FAULT FEATURES OF SALTON BASIN, CALIFORNIA[1]

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OUTLINE

GENERAL FEATURES

The Salton Basin is a great natural depression in the southeastern corner of California (Pl. I). Its lowest elevation is 273.5 feet below sea-level,[2] and the lowest part of the basin is now occupied by the more or less ephemeral lake known as Salton Sea, which was created in 1905 by the accidental escape of Colorado River during the diversion of irrigating water to Imperial Valley. Physiographically, Salton Basin is continuous with the depression occupied by the Gulf of California, and the only topographic barrier that prevents the access of sea-water to the basin is a delta dam built up in recent geologic time by Colorado River. At its lowest point this dam is less than 50 feet above sea-level.

SURROUNDING MOUNTAINS

The axis of the basin trends southeast-northwest, and at its northwest extremity the basin narrows nearly to a point, being connected by San Gorgonio Pass to the Pacific Slope. Mountain ranges from 2,000 to 10,000 feet in height flank the basin on the

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[2] There is some question as to whether the exact elevation of the lowest point of the basin, now covered by Salton Sea, is −273.5 or −287 feet. See *U.S. Geol. Surv. Water-Supply Paper 213*, p. 30, for discussion and statement that former figure is probably correct.

northeast and southwest, reaching their highest elevation in the vicinity of San Gorgonio Pass, where the basin is narrowest. The mountains on the southwest are generally known as the Peninsular ranges. They extend down into Mexico, and form the crest of the peninsula of Lower California. They include the San Jacinto, Santa Rosa, Vallecito, and Laguna ranges, and their crest separates the drainage of Salton Basin from that of the Pacific Slope. The summit of the Peninsular Mountains is well watered and generally timbered. Along it there are numerous tracts of gently rolling land sculptured into only a moderate relief. Such are Pinyon Flat, Montezuma Flat, and the region near Jacumba. These tracts are doubtless remnants of the surface of the region before it was uplifted to form the present mountain chain. The eastern slope of the Peninsular ranges, however, is precipitous, and its dissection deep.

The San Bernardino Mountains and other ranges form the northeast wall of the basin. To the southeast these break up into a series of low, disconnected ranges. All of them are barren rock masses, at whose feet are gathered great débris fans.

THE BASIN FLOOR

A great part of the basin floor is a monotonous plain formed of alluvium brought in from every side. In the center the alluvium is fine silt, but at the mountain borders it is a coarse fanglomerate. Over some of the basin floor there is a considerable deposit of sand in the form of dunes. About the borders there are, at various places, exposures of soft, folded, sedimentary beds, which have been carved into picturesque badlands. Since the basin is practically rainless, vegetation is scant, and restricted to desert plants, such as creosote, cacti, ironwood, and, at places, mesquite.

One other feature of the basin floor deserves mention. Near its center, at the southeast end of Salton Sea, is a large group of active mud volcanoes, associated with small exposures of recent lava (obsidian).

STRATIGRAPHY

The rocks of Salton Basin have been studied in detail at only a few places. For the purposes of this paper, however, they fall naturally into three classes. The first class comprises pre-Tertiary

crystalline rocks, and forms the basement rock of all the region. There are large bodies of schist and gneiss, and smaller amounts of marble and quartzite. The age of these metamorphics is unknown. Most of them are Paleozoic, but a part probably is pre-Cambrian. Then there are still greater masses of granite, monzonite, and diorite intruded into the metamorphic rocks. These intrusives are probably Mesozoic. The various crystalline rocks constitute the mass of all the mountain ranges.

The second division of rocks consists chiefly of sedimentary beds of late Tertiary age. The series has a total thickness of several thousand feet, and consists of sand, shale, and conglomerate, with some salt and gypsum. Generally the beds are more or less folded and broken, but they are everywhere soft and poorly consolidated. On them is developed the badland topography mentioned above. In the Carrizo Creek region these beds contain an abundant late Tertiary marine fauna. Elsewhere they are apparently unfossiliferous, and probably terrestrial in origin.

Interbedded with the Tertiary sediments at some places are beds of basaltic lava and tuff sometimes 100 to 200 feet in thickness. These volcanics constitute only a small portion of the series.

Quaternary alluvium is the last division of the rock section. It forms most of the basin floor, and fills many of the adjacent valleys. Its areal extent is greatest of the three classes.

FORMATION OF SALTON BASIN

Salton Basin has evidently existed as a marked depression since times previous to the latter part of the Tertiary period, for it has received sediment during the formation of the last two rock series. Neither the Quaternary nor the Tertiary sediments are displaced by any such vertical movements as must have occurred during the formation of the basin. The Tertiary beds are seldom found at elevations above 1,000 feet, and the Quaternary shows but few recognizable displacements and these are of small size.

It has been tacitly assumed by geologists that the basin originated as a dropped fault block, or graben. This hypothesis, suggested by the topographic features, is greatly strengthened by the fact that the basin lies directly on the course of the San Andreas

rift, a notable fault along which occurred the displacement that caused the San Francisco earthquake of 1906. The California Earthquake Commission traced this fault continuously from San Francisco southeastward to the very tip of Salton Basin. In its report[1] the commission suggests that the rift probably continues southeast, and is connected in some way with the formation of the basin. In the Peninsular Mountains, southwest of the basin, there are also several well-recognized faults, portions of which have been mapped, but these have generally not been traced eastward to their visible terminations. These faults and their relation to the faults described here are shown in Figure 1.

The evidence of faulting in this region is as a rule, derived from the topography, and can only rarely be established by stratigraphic criteria. Igneous and metamorphic rocks, such as compose the mass of the mountain ranges, are so homogeneous in nature that it is often impossible to determine differences in the rocks exposed on either side of a fault, while the Quaternary material which fills most of the valleys has been deposited since the faulting occurred and obscures it in many places.

THE INDIO FAULT

At the base of the crystalline ranges (Little San Bernardino, Orocopia, etc.) bordering the upper part of the northeast side of the basin, lies a conspicuous chain of low, badland hills in which are exposed the late Tertiary sedimentary beds, and occasionally small patches of the underlying bedrock. This chain of hills is separated by a slight break into two ranges known as the Indio Hills and Mecca Hills. The Indio Hills have a total length of 20 miles, and a width of 2 or 3 miles. The Mecca Hills are also about 20 miles long, and at some places are 4 or 5 miles wide. The general slope of the hills is southwest, where they dip beneath the basin floor. They are separated from the crystalline ranges northeast by a trough from 1 to 3 miles in width filled with coarse alluvial débris. At some places the canyons that head in the main mountains cut entirely across the hills, as at Shaver Canyon and the Thousand

[1] *California Earthquake Commission Report*, Carnegie Inst. of Wash., 1910.

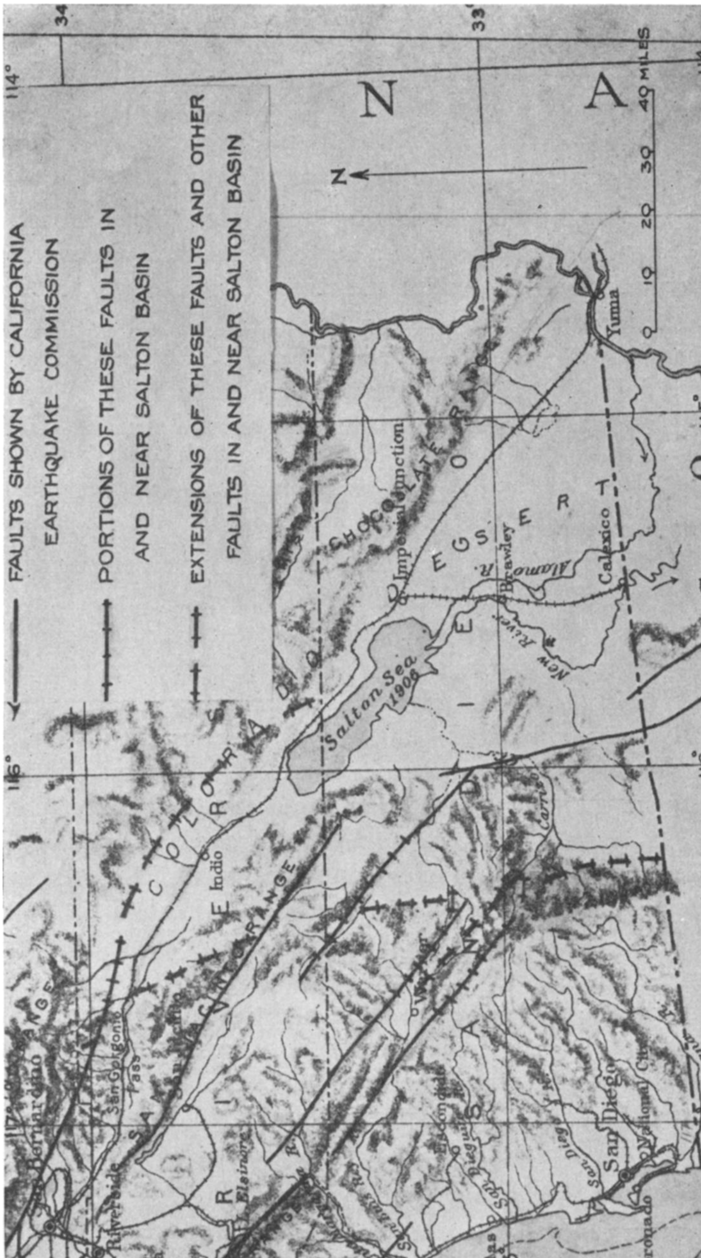

FIG. 1.—Prominent faults of Southern California. (After California Earthquake Commission)

Palms. At other places they are deflected by the foothills into long, longitudinal valleys between the crystalline and Tertiary rocks.

The Indio and Mecca Hills have undoubtedly been lifted from the basin floor by a fault for which the name of Indio fault is suggested. This fault passes along the northeast border of the hills formed by the Tertiary rocks. Near Indio there is for several miles a steep and very perfect scarp, generally not more than 100 to 300 feet in height. The broken Tertiary beds dip southwest from the present face of this escarpment at angles of about 45°. Along the northeast side of the Mecca Hills the scarp is less perfect, but still constitutes a very well-defined ridge. West of Dos Palmas it is a low bluff along the east base of a point of clay hills.

Although the Indio fault as here described was observed only at a few scattered points, it appears reasonably certain that it extends throughout the length of the Indio and Mecca hills. The most critical point at which it should be examined is the contact with the crystalline bedrock in the Orocopia Mountains, where there appears to be no marked separation of the crystalline range from the bordering sedimentary foothills. The fault doubtless continues at least as far south as an isolated hill of Tertiary material near Durmid, which has probably been elevated in the same manner as the hills farther north. Its total length, then, is about 50 miles, and its form an arc of gentle curvature. Its northwestern end has a trend nearly west, and lies in the direct line of probable extension of the San Andreas rift, from which the actual separation is only a few miles in length. The conclusion seems justified that the Indio fault represents the extension of the San Andreas rift. At the southeastern end the fault-trend is more nearly south, and points suggestively toward the mud volcanoes.

It should be noted that the throw of this fault is opposite to that of the San Andreas rift farther northwest, and also to the original displacement which must have formed the Salton Basin. Such reversals of throw along prominent fault lines are, however, neither impossible nor uncommon,[1] and occur at several places along the course of San Andreas rift farther northwest.

[1] The Bright-Angel fault in the Grand Canyon is a case in point. *Science*, April 24, 1908, p. 667.

FAULTS SOUTHWEST OF SALTON BASIN

The faulting along the southwestern side of the basin is apparently of two ages, and took place in somewhat different directions, the intersection of the two fault systems probably accounting for the present irregular outline of the basin. Thus great mountain salients, such as the Santa Rosa Mountains, the Vallecito-Fish mountain spur, and the projection of the Peninsular Mountains along the Mexican Boundary, are separated by big re-entrant valleys, such as San Felipe Valley and the Carrizo Creek Valley.

The oldest of these fault systems, if this inference is correct, has a strike about N. 10 W. and is represented by three notable escarpments. One lies along the east base of the San Jacinto Mountains, passing up Palm Canyon. Another is at the west side of Borego Valley. The third extends from Agua Caliente Springs southward up Carrizo Gorge, along the east face of the Laguna Mountains.

Evidence of a fault along the northeast and east face of Mount San Jacinto was obtained near Whitewater. Just west of Whitewater Point the mountain face is composed of pink and gray granite, and of a grayish marble. The marble and granite are arranged in layers turned on edge with a strike about N. 20 W., and a dip of 75° or more to the northeast. Although the quantity of marble is much less than that of the granite it constitutes a considerable part of the mountain mass, the layers ranging from a few inches to 50 feet in thickness. The alternation of rocks is well exhibited in a prospect tunnel in Sec. 23, T. 3 S., R. 3 E., where the material penetrated has the appearance of a gigantic fault breccia, and the contact surfaces are abundantly slickensided. This intermixture of material probably resulted from step-faulting, the successive breaks along many parallel lines causing an intimate mixture of the different rocks. Associated with this prominent fault line is the warm spring at Palm Springs, whose water is believed to be derived from granitic rocks[1].

West of Borego Valley no observations were made to confirm the existence of a fault except to note that the mountain front in that region is a very steep and straight escarpment from 2,000 to 4,000 feet in height.

[1] The inference is based on unpublished analytical data.

The southernmost fault scarp of this series was observed in Canebrake Canyon, and at Agua Caliente Springs. At both places the mountain front for several hundred feet from the lowland border consists of rotten, grayish granite, broken into minute joint blocks, kaolinized, and altered. Farther in the interior of the mountains the rock is dense and unweathered. There is much evidence of hydrothermal alteration, a very natural thing to expect, at Agua Caliente Springs, where a large number of springs, part of which yield warm water, issue from the granitic rocks.

Cutting across this first system of faults is a system which strikes approximately N. 45 W., and which is represented by several prominent faults. The most northerly fault of this system is the San Jacinto fault, which passes south and west of San Jacinto Mountains, extending through Hemet Valley and down Coyote Canyon. For several miles it traverses the northeast side of Borego Valley.[1] The uplift along this fault was on the northeast. Coyote Mountain on the northeast of Borego Valley is part of a prominent spur elevated in this uplift, and is bordered on the southwest by well-defined scarp, which displaces Tertiary beds. It is probable that the San Jacinto fault extends at least as far as Borego Mountain, but it is much obscured in that direction by recent alluvial deposists. Movement occurred along this fault at the time of the San Jacinto earthquake of 1899.

Several faults which have been recognized in the vicinity of Warner Valley[2] extend southeastward into the western part of this region. One of these which passes nearly through Warner Hot Springs traverses Grapevine Canyon, turns nearly east along a part of San Felipe Creek, and disappears near The Narrows. Its uplift was on the northeast, and the tongue of granitic rock south of Borego Valley and in the vicinity of The Narrows is believed to have originated from the uplift. A fault extends from Warner Valley down the headwaters of San Felipe Creek, and its eroded scarp forms the northeast side of San Felipe Valley, being a promi-

[1] H. W. Fairbanks, *California Earthquake Commission Report*, Carnegie Inst. of Wash., 1910, p. 47.

[2] A. J. Ellis, and C. H. Lee, "Geology and Ground Waters of the Western Part of San Diego County, Cal.," *U.S. Geol. Surv. Water-Supply Paper 446*.

nent mountain wall for 12 or 15 miles. Another fault passes through Banner Canyon and Rodriguez Canyon, and extends along the north side of Mason Valley and Vallecito Valley, the mountain walls of these valleys probably representing considerably eroded fault scarps. The last two faults unite in the vicinity of Agua Caliente Springs, and are not known to continue farther, but may extend along the north side of Carrizo Valley at the base of Vallecito Mountains and Fish Mountains.

VALLEYS FORMED BY FAULTING

Associated with the second system of faults are several peculiar valleys for whose formation the faults have been responsible. The largest of these valleys are Borego Valley, San Felipe Valley, Mason Valley, and Vallecito Valley. Collins Valley, adjacent to Borego Valley, and a little valley less than a mile in extent at Banner, were formed in the same way. All of these valleys have for their northeast boundary a high, steep mountain wall which originated as a fault scarp along some one of the faults mentioned above. Thus Borego Valley and Collins Valley lie southwest of the San Jacinto fault. The general shape of each valley is triangular, and the south and west sides are much more irregular in outline than the northeast side, the mountainous borders on these sides being also somewhat less abrupt than those on the northeast. Most of the valleys are high at the southwest, and the drainage is to the northeast. This has probably been the natural result of the tilting of the faulted strips, which have all been dropped down on the northeast and elevated on the southwest.

Most of the faults have forced the drainage to follow northwest-southeast directions, particularly in the various canyons such as Coyote Canyon, Grapevine Canyon, and Banner Canyon, but some streams, such as San Felipe Creek, northeast of San Felipe Valley, and Banner Creek at Banner, occupy deep gorges which cut directly across the fault scarps at the northeast border of these valleys. It is probable that these streams existed before the faulting, and that the faulting took place gradually, the streams cutting down as fast as the rocks were lifted across their beds. A further suggestion that the earlier drainage lines may have had a northeast trend is

afforded by the granite ridges which divide some of the valleys. San Felipe Valley, for instance, is cut nearly in two by a low spur of granitic rock projecting from the southwest, while Mason Valley and Vallecito Valley are entirely separated by such a ridge, except for a very narrow, rock-cut canyon. These ridges may very likely represent drainage divides which existed before the faulting.

TYPE OF FAULTING

Most of the faulting observed is of the normal type. The Indio fault is associated with much folding, and it is possible that it may be in part due to thrust movements.

AGE OF FAULTING

The age of the various faults is very difficult to establish, since the age of the rocks displaced is so indefinitely known. The original settling of the Salton Basin must be pre-late Tertiary in age, because in the resulting basin great thicknesses of late Tertiary sediments were deposited. Considerable faulting has occurred since the deposition of these beds, such as that along the Indio fault, and the San Jacinto fault where Tertiary beds are displaced. The fact that movement has occurred along the recognized fault lines during recent notable earthquakes in California indicates that some of those faults are still active; and the excellent state of preservation of many of the scarps suggests that much of the displacement along some of them has occurred in Quaternary time.

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